BDSS Prototype Implementation: A Behavioural Approach to Sonifying Photosynthetic Systems[1]

Hee-Eun Kim*

Abstract

This document presents a concise overview of an experimental sonification methodology currently under development, referred to as Behaviour-Driven Systemic Sonification (BDSS). BDSS proposes a sonification framework that prioritises system behaviour and temporal interdependence over isolated parameter mapping. The method is tested using a simulated photosynthetic system, comparing three mapping strategies (Linear, Conditional, and BDSS). This summary outlines the methodological design, differentiating logic of each mode, and highlights implications for future applications in both scientific and artistic domains.

Supplementary Materials

A/B/C Mode Comparison Video: https://www.youtube.com/watch?v=U3tuYjfow6o

[1] This summary report is intended for public documentation and early dissemination of work-in-progress. It is not a peer-reviewed publication and excludes citations to unpublished or in-progress research.

* Independent Researcher, New Media Artist

1. Introduction

Sonification has traditionally been defined as the use of non-speech audio to convey information or perceptualize data (Hermann et al., 2011). Common approaches include direct parameter mapping, auditory icons, and event-based logic. While these methods have provided significant utility across fields such as medical diagnostics and human-computer interaction, many sonification strategies remain rooted in static representations, lacking the capacity to express interdependent or emergent behaviours.

BDSS (Behaviour-Driven Systemic Sonification) proposes an alternative model that treats sound as an expressive medium for systemic behaviour. Inspired by ecological modelling, auditory display research, and systems theory, BDSS moves beyond symbolic mapping and aims to render multi-variable entanglement, relational feedback, and dynamic adaptation through sound. This summary introduces the BDSS framework and describes its initial implementation through a simulated photosynthetic model.

2. Methodology Overview

A web-based simulation was developed using JavaScript and the Web Audio API. The simulation models five interdependent variables commonly used in plant physiology:

- Photosynthetically Active Radiation (PAR)
- Temperature
- Stomatal Aperture
- Transpiration Rate
- Stress Index (derived from environmental and physiological thresholds)

Three sonification strategies were designed for comparison:

- **Linear Mapping (Mode A):** Each variable modulates a sound parameter independently, maintaining fixed and direct relationships.
- **Conditional Mapping (Mode B):** Sound output changes based on threshold-based logic (e.g. IF temperature > 25°C THEN cutoff frequency = high).
- **BDSS Mapping (Mode C):** Variables modulate one another over time. Sonification reflects continuous and interdependent system behaviour.

Sound synthesis was implemented using a shared modular engine including harmonic oscillators, filtered noise, amplitude modulation, and frequency detuning. Audio parameters were updated at 10Hz, with identical audio architecture across modes to isolate differences in mapping logic. Mathematical formulations followed simplified models from plant physiology literature (Jones, 1992; Taiz & Zeiger, 2010).

3. Observations and Findings

Each sonification mode—Linear (Mode A), Conditional (Mode B), and Behaviour-Driven (Mode C)—produced distinct perceptual effects when applied to the same underlying simulated data. A structured A/B/C test was conducted using identical synthesis architecture to isolate differences in mapping logic.

- **Mode A (Linear Mapping):** Produced smooth but overly predictable sonification. Each parameter (e.g. light, temperature) influenced a sound feature independently (e.g. amplitude, cutoff), leading to a flat perceptual texture. There was no sense of system integration or expressive dynamics.
- **Mode B (Conditional Mapping):** Introduced contrast through binary logic gates (e.g. if temperature > threshold), resulting in sharper transitions. However, the

mappings remained discrete and rule-based, often producing abrupt, mechanical-sounding changes lacking continuity or nuance.

- **Mode C (BDSS):** Generated continuous, dynamically evolving sound patterns that reflected the interdependence between variables. Emergent behaviours—such as rhythmic swells, tension-and-release patterns, and spectral shifts—appeared to correspond with internal state changes. Listeners perceived this mode as more "systemic," "harmonic," or "alive," even when unaware of the structural logic behind it.

These findings suggest that BDSS better expresses systemic entanglement and temporal evolution, which could improve interpretability of complex data and foster emotional or intuitive engagement with underlying processes.

4. Limitations and Discussion

While the BDSS framework demonstrates promising results in simulated environments, several limitations must be noted:

- The current simulation does not incorporate real biological data or environmental sensors; all behaviour is modelled using mathematical approximations.
- No formal perceptual testing has been conducted beyond informal listening reports; user interpretation remains anecdotal.
- The stress index, although behaviourally constructed, may lack biological fidelity without empirical calibration.
- Only a limited set of sonification modes (Linear, Conditional, BDSS) were tested; additional comparison models (e.g. auditory icons, auditory graphs) could provide deeper validation.

- The system currently assumes a fixed synthesis architecture; future iterations could test whether different sound synthesis models affect perception of system behaviour.

These limitations suggest that BDSS should be considered an early-stage exploratory framework. Its strength lies in conceptual design and potential for cross-domain application, but further empirical and perceptual research is required.

5. Implications and Future Directions

BDSS opens pathways for both scientific and artistic exploration. Rather than fixing a single goal or application, this summary outlines three broad directions:

5.1 Scientific Implication

BDSS may serve as a tool for ecological monitoring or biological modelling by allowing auditory perception of stress, synchrony, and environmental response. A proposed next step would involve comparing the BDSS simulation output to real-world biological datasets (e.g. photosynthesis recordings, environmental sensor networks) to test whether behavioural sonification can reveal patterns not easily captured through conventional visualisation. This could expand auditory display methodologies within ecological and environmental sciences (Kramer et al., 1999).

5.2 Artistic Implication

BDSS also holds potential in interactive sound art and generative systems. A future artistic implementation would involve porting the BDSS engine into a live, node-based environment such as TouchDesigner, where real-time interaction could modulate behaviour. The installation could respond to lighting, proximity, or gesture, offering a dynamic sonic environment that evolves based on both environmental variables and internal systemic logic.

5.3 Technical Applications and Expanded Frameworks

A further direction includes integrating BDSS with hardware-based sensing and control systems—such as Arduino, Raspberry Pi, or other microcontroller platforms—to enable real-time behavioural sonification in robotics, interactive installations, or mechatronic systems. By incorporating sensors for temperature, light, moisture, or proximity, BDSS could be deployed in environments where sound expresses systemic state. This would support applications in responsive objects, ecological sculptures, or educational tools for systems thinking.

While the current implementation focuses on biological simulation, BDSS is not limited to biological data. The decision to use photosynthesis was based on its rich, interdependent variables and temporal, environmentally responsive behaviour—ideal for testing systemic sonification. However, any dataset exhibiting behavioural dynamics could be modelled using BDSS principles.

A future direction could include developing a programmable BDSS engine, where users upload arbitrary datasets and the system automatically parses interrelations, generates signal logic, and produces behaviourally aligned sound. Such a platform could enable wide adoption of BDSS across domains such as urban modelling, finance, social dynamics, or climate systems.

References

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